Carnegie Mellon
Software Engineering Institute

Guidelines for Developing a Product Line Concept of Operations

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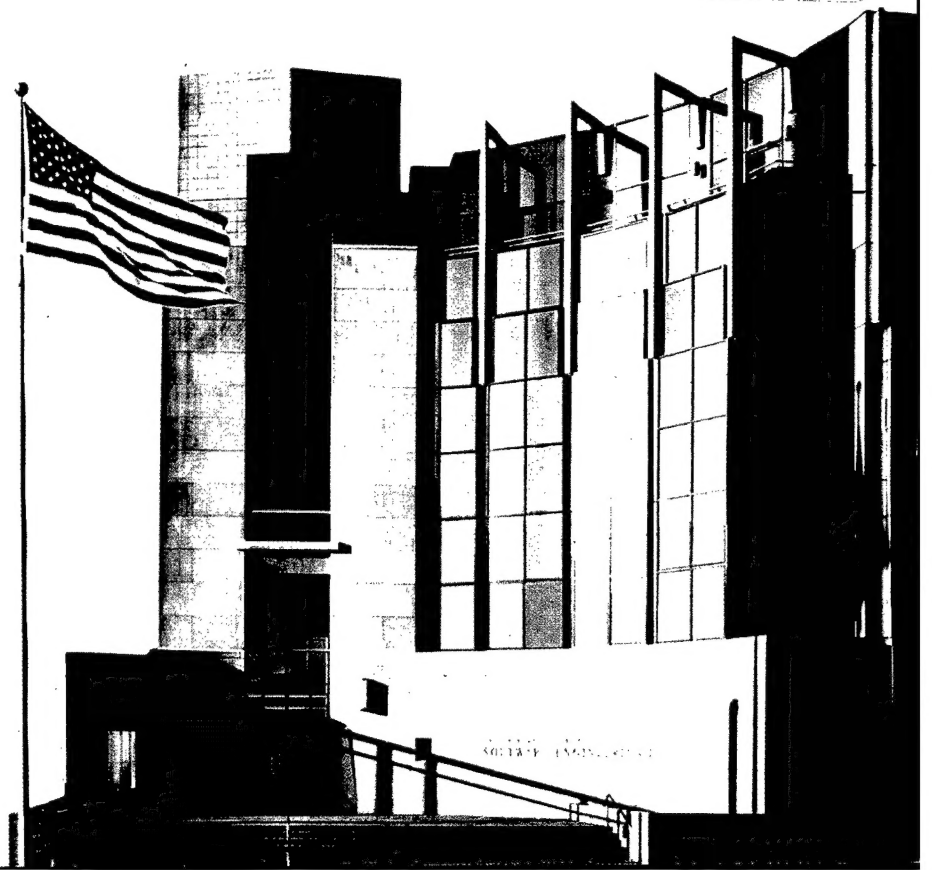
Sholom Cohen

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Product Line Practice Initiative

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Preface

Moving to a Product Line Approach

When an organization makes the decision to move to a product line[1] approach for acquiring or developing software, it must address several key issues:

1. What constitutes the product line?
2. How will the product line be introduced?
3. What are the key organizational elements involved in defining, developing, and fielding the product line?
4. What is the relationship between the product line assets and systems within the product line?
5. How will the architecture be developed and maintained?
6. What are the sources of software components and other assets?

The decisions regarding these and several other key questions establish the basis for a product line. As these decisions become operational, the organization establishes a process for fielding the product line. The definition, development, and maintenance of this process require an operational concept[2] in order to

1. describe the characteristics of the process for fielding the product line from an operational perspective. (Included in fielding are product line development or acquisition and product line sustainment throughout its life.)
2. facilitate understanding among stakeholders of the goals of this process. Stakeholders for the product line include developers and users of the products of the process.
3. form an overall basis for long-term planning for the product line and provide guidance for the development of specific product line outputs such as a Developers' Guide, Business Plan, Architecture, and other assets.
4. describe the organization fielding the product line and using product line products.
5. define the role acquisition will play and solidify the general acquisition approach. Acquisition will include procurement strategies for asset development, product development, and/or needed contractual products and services.

As the product line is fielded, the operational concept provides a baseline when the organization considers alternatives in its approach as changing conditions warrant.

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[1] Detailed information about product lines and related technology can be found in the Product Line Framework [Clements 99].

[2] Based on: "Guide for the Preparation of Operational Concept Documents" ANSI/AIAA G-043-1992 [AIAA 93].

The Concept of Operations

The operational concept for a product line should be documented as a Concept of Operations (CONOPS). It is generally the purpose of a CONOPS to represent the *systems user's operational view* for a system under development. This operational view is stated in terms of how a system will operate in its intended environment. In the case of fielding a product line, we are discussing a process rather than a system; the users of that process include a wide range of stakeholders for the product line. The CONOPS for that process will accomplish much the same purpose as a CONOPS for a system by describing how the mission or purpose of the product line will be fulfilled, the environment for fielding the product line, and the organizational structure for its fielding. Specifically, the CONOPS for a product line will contain the following:

1. how - the strategies, tactics, policies, and constraints that describe *how* the product line process will be used to field the product line

2. who does what - the organizations, activities, and interactions that describe *who* will participate in fielding the product line and *what* these stakeholders do in that process

3. when - the specific operational processes, in overview fashion, that provide a process model for fielding the product line in terms of *when and in what order* these operational processes take place, including such things as dependencies and concurrencies

Role of Development and Acquistion

This report provides guidelines and examples for a variety of development or acquisition approaches. The report is intended for government organizations, government contractors, and commercial organizations. Software assets for a product line enter these organizations through one of three ways: the organization develops it (builds it itself, either from scratch or by mining legacy software), purchases it (buys it, largely unchanged, off the shelf) or commissions it (contracts with someone else to develop it especially for them). The organization may use its assets in house for product development or may again commission someone else to use the assets for development of products. Government acquisition of product lines is most often achieved by commissioning both asset and product development, although some government organizations maintain in-house development groups.

The CONOPS should spell out the specific product development strategies and the role development or acquisition will play in fielding the product line. These development and acquisition approaches may involve a combination of government, government contractors or purely commercial activities operating under widely different circumstances:

1. A government organization may acquire software systems as part of a product line. Several alternatives exist for this acquistion process, including: commisioning all product line development, in-house scoping of the product line and development of an architecture, contractor development of the architecture, or contractor development of products from government assets.

2. A commercial organization develops its own architecture, components, and other assets. These are used to provide individual products in the product line internally or to external customers. A government contractor may elect to develop assets in anticipation of future

contract work. An alternative may see a commercial organization contracting, like the government, for product line assets.

The guidelines in this report do not illustrate every possible combination and alternative that could be covered by a CONOPS, but do indicate where the alternatives will affect decision making. An organization develops its CONOPS to establish the desired product line approach that it wishes to take. These guidelines recommend a detailed description of the selected approach and possible presentation of alternatives. The resulting CONOPS documents the decisions that define the approach and the organizational structure needed to put the approach into operation.

Using the CONOPS

The CONOPS should relate a narrative of the process to be followed in fielding the product line. It must also speak to the various product line stakeholders. The CONOPS addresses these needs through describing the process and organization for fielding a product line and also listing key action steps for putting the CONOPS into effect. While the CONOPS does not provide a complete process model, it does provide sufficient detail to help relate core assets and system products to the development organizations producing or using them.

The guidelines are not, however, intended to support an implementation or transition plan since they do not provide managers with the detailed steps involved in planning for the transition—for example, establishing accountability, managing risk, scheduling, and budgeting. The guidelines do offer a clear set of steps to realize the goals and objectives of the product line approach to software development/acquisition of core assets and of systems within the product line.

A CONOPS should address a number of key product line issues both for core asset and product development. An organization needs to address these issues as it makes product line decisions. For product development, the guidelines will help address the needs of program managers, developers and others in a product oversight or decision-making role. The guidelines also apply to the needs of future reusers of product line assets who will be building derivative systems. The issues may be grouped into categories as shown in the following table.

Categories	Core Asset Development	Product Development
Key decisions	Process and organization for developing core assets; key action steps for putting the CONOPS into effect	Process and organization for developing products in the product line
Components	Known components or elements in the product line including the product line scope, the architecture and other assets, and the product line activities	Effects of using product line assets in developing products
Context	Relationships among the stakeholders and sources for asset development: legacy systems and assets, asset developers and product users	Relationships among the stakeholders and assets for product development: product line assets, asset developers, product developers and product users
Activities	Sequence of activities moving from product line scoping, through architecture, and component development. Product line sustainment	Activities for using core assets in the development of individual products
Organizational elements	Organizational elements and the role they play in fielding the product line	Organizational elements and the role they play in the development of product line products
Rationale	Rationale for moving to a product line approach as well as risks	Rationale for using product line assets as bases for product development
Integration	Tie together the above elements to provide guidance in development activities such as the development of component assets and the use of the architecture and assets in producing products	Production plan for products in the product line. Guidance is especially important for reflecting the results of using core assets in product developments to support their continued improvement

Table 1. Product Line Issues Addressed by the CONOPS

The guidelines recommend that a CONOPS should provide a forum for exchange of information on major technical and programmatic issues among the stakeholders. This will

result in a common understanding of the goals for the product line, the structure of the product line organization and the steps to be taken in fielding the product line.

Using This Report

This report serves a dual responsibility with regard to supporting an organization that has decided to field a product line:

1. The report provides a standard outline and describes the class of information to be contained in each section of a CONOPS for a product line.
2. The document provides examples from CONOPS adapted for presentation in the guidelines.

Having decided to field a product line, the organization should use the guidelines and examples from this report as a starting point for crafting its own CONOPS. The user of this document should follow the guidance in each section to generate specific sections of the CONOPS. With that approach in mind, each chapter of this report is organized as follows: overview of subsections, followed by guidance to generate each subsection of the CONOPS, supplemented by examples.

Some organizations may feel that the term "Concept of Operations" should apply only to system developments. In that case, they may wish to use the title "Product Line Approach." We prefer to apply the term CONOPS because it conveys the operational nature of the process for fielding a product line. Organizations need not stick rigidly to the structure provided here. This report should serve to guide the development of the organization's operational concept. If information contained here is not required, it should be omitted or other information should be substituted.

The guidelines in this report are based on several CONOPS developed over a period of three years for organizations working to field product lines. During that time, the CONOPS has gone through several rounds of reviews, changes, and major revisions. The guidelines have been distilled to a form suitable for use by government, government contractors, and commercial industry. In using this report, you will no doubt find areas that proved helpful or that were difficult to apply. Your comments are appreciated and will be useful in improving the quality and applicability of the guidelines for other users.

An excellent set of reviewers made possible the production of the Guidelines. I would like to acknowledge the contributions of Matt Fisher, Nelson Weiderman, John Bergey, Linda Northrop, and Paul Clements who provided thoughtful and extensive reviews.

Sholom Cohen
May 1999

Abstract

This report provides guidelines for an organization that is developing a Concept of Operations (CONOPS) document. A CONOPS document defines the organization's product line approach. The CONOPS document and the decisions made in its preparation will guide the organization as it plans and executes the process of fielding a product line, from product line scoping, through architecture, component development, and product development.

Organization of This Report

The chapters of this report represent a template for the chapters of an actual CONOPS. For preparing a CONOPS, this report presents chapter-by-chapter guidelines and practical examples of their application. Each section of the report also presents a key set of decisions that the organization must make to complete the contents of that chapter and action steps to bring those decisions into operation. The report is organized into chapters to present guidelines in each of the following areas:

1	Overview	Product line concepts and guidelines for describing the product line
2	Approach	Guidelines for describing the approach for fielding products in the product line
3	Product line background	Outline for presenting information on existing systems or other motivation for the product line
4	Organizational considerations	Guidelines for establishing the product line approach and management structure
5	Technical considerations	Guidelines for establishing process steps, methods, and assets including architecture
6	Recommendations	Guidelines for setting up initial organizations and assigning responsibilities
	Appendix A	Key questions to be answered

Table 2. Contents of a CONOPS Report

Chapter 7, Summary, provides the reader with a summary of this guidelines report and would not be a part of a typical CONOPS.

This document uses two examples for illustrating CONOPS sections:

- ACMYWorks represents a set of assets for the pager market. The developer of ACMYWorks, ACMY Corporation, has a legacy of pager systems, but is losing market share to off-shore sources. To capitalize on their experience, they are developing ACMYWorks as a set of assets for the high-end pager product line. ACMYWorks will be used in ACMY's new products and will be sold as a product line support asset base for other pager developers.

- Battlefield2000 is a set of assets to support systems for battlefield command and control missions. The assets were commissioned by a DoD organization. The DoD will foster their use in new battlefield C2 systems that will be contracted to the Battlefield2000 developer and to other DoD contractors.

In addition to examples, the guidelines include the following:

- specific product line issues that an organization should address
- recommended actions that the organziation should take

in fielding a product line. Issues appear near the beginning of sections or subsections where they should be addressed. Actions appear at the end of sections and subsections.

1 Creating the CONOPS Overview Chapter

The overview section of the concept of operations (CONOPS) should identify the product line and its context. It must establish the purpose of the CONOPS document, provide basic product line concepts, and explain to readers why the organization is adopting a product line approach. This section should also establish the readership for the CONOPS and describe the content of each section.

The CONOPS Overview chapter is organized into the following sections:

Identification	Identifies the product line and its context
Concepts	Provides some basic definitions of concepts behind the approach
Product line variation	Discusses parameters of the product line development (how development is accomplished, shared responsibilities, nature of product line, greenfield[3]/legacy, etc.)
Readership	Explains the message the CONOPS delivers to each stakeholder and provides an overview of contents

A product line approach for product development usually represents a major change in an organization's way of doing business. An organization produces CONOPS document to describe how a product line approach will operate within the organization. A broad set of product line issues must be discussed and resolved by a wide range of stakeholders. The audience for the CONOPS includes the following product line stakeholders: asset developers, product developers, management at various levels, product users or their representatives, and support organizations. The topics covered in a CONOPS arise from various decisions made by the stakeholders about the product line. These decisions include

- product line scope
- development processes
- assets to be developed

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[3] A greenfield effort is a development not constrained by prior systems. The name is derived from major construction efforts. For example, the Denver International Airport was a greenfield effort; the new Reagan-National Airport was constrained by existing terminals, runways, rivers, highways, etc.

- architecture for the product line
- production plan for product line products
- role development/acquisition will play
- plan for introducing the product line

This is not meant to be an exhaustive list, nor are these decisions independent of each other. There is significant overlap. Ideally, the CONOPS should provide a narrative that describes how the product line approach will be introduced, who will be responsible for its introduction, and what methods will be applied.

1.1 Guidelines for Defining the Product Line and its Context

A key decision to be made by the organization is the following:

> *Issue #1. What is the product line? What mission or application area will be satisfied by systems in the product line?*

The CONOPS should capture this decision by both identifying the product line and defining the class of systems for which it will apply. For example, an organization may be developing an asset base to support products in the pager market. In that case, the product line and product line CONOPS should be described as follows:

> *ACMYWorks is a collection of assets that will support a product line of pager products. The ACMYWorks CONOPS presents a cooperative methodology for developing ACMYWorks and using its assets to produce systems. The reader is introduced to the ACMYWorks organization and processes. A rationale for the change from historical practice leads to a convincing argument on the need for shifting to a concept of operations based on a product line approach for development of new pager systems.*
>
> *User involvement is a key element of fielding the product line and ACMYWorks assets. With this in mind, the CONOPS addresses the following topics .... An analysis of the advantages and challenges of the new approach and some implementation issues are also presented.*

A decision parallel to that of product line description involves the approach for developing or acquiring a product line:

> *Issue #2. How will product line assets and product line products be developed or acquired? Is there an acquisition/supplier relationship?*

An organization may choose one of several paths in addressing this issue and may even have a hybrid approach. The paths include the following:

- developing assets and products in house
- commissioning the development of assets or products
- purchasing assets off the shelf for building products in house

The CONOPS should clearly state the approach the organization will take. A pure development approach may be described as follows:

> *The ACMY asset development group will specify and develop ACMYWorks. The pager product group will build new pager systems using those assets.*

Another organization may decide that internal development costs are too high and may out-source much of the asset development:

> *This CONOPS describes the approach ACMY will take for working with vendor(s) who will build ACMYWorks to our specification. Product developers internal to ACMY will use ACMYWorks to field our line of pager products.*

A government organization without in-house development staff may acquire through contractors both the assets and products for the product line. In this case, the CONOPS will describe the organizational responsibilities for both government and its contractors in developing assets and using assets for individual products. For example:

> *The Battlefield2000 assets will be developed by our prime contractor. The Battlefield2000 contractor along with other qualified contractors will use those assets in the development of battlefield command and control systems.*

A hybrid approach could, for example, provide for in-house development of certain key assets (e.g., domain models, architectures, and foundation frameworks), with other assets and product development out-sourced to contractors. In all cases, these decisions should be clearly defined in the opening section of the CONOPS. The remainder of the CONOPS document provides the details of the approach.

1.2 Guidelines for Introducting Product Line Concepts

This section of the CONOPS should present basic product line concepts. For many stakeholders, the CONOPS will be the first exposure to the product line approach. For this reason, the CONOPS must provide some basic definitions of concepts behind the approach. Basic terminology, drawn from *A Framework for Software Product Line Practice* [Clements

99], will support this section. The organization will add detail pertaining to their approach. Key terms might include the following:

> *Product line - A software product line is a set of software-intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment or mission. A new pager product will be produced by taking applicable components from ACMYWorks, tailoring them as necessary through pre-planned variation mechanisms such as parameterization, adding any new components (e.g., pager-unique software developed by the ACMY product groups) that may be necessary, and assembling the collection under the umbrella of the ACMYWorks product line-wide architecture. Building a new pager product becomes more a matter of generation than creation; the predominant activity is integration rather than programming.*

> *Commonality/variability (also called domain engineering) - Asset development for a product line can be characterized by capturing the commonalities among its members and by factoring the ways in which members vary from each other. ACMYWorks features certain functions common to all planned pager systems. But each of these pagers is different from the rest, featuring certain capabilities and satisfying requirements unique to it.*

> *Product development (also called application engineering) - Pager products can be most efficiently produced by taking advantage of the commonalities, while planning for the variations. ACMYWorks will provide a platform of core assets that (a) largely implements the functionality common across the product line; and (b) can be easily tailored to account for the variability when building an individual system. Producing any single member of the product line is much less expensive than if it were built entirely from scratch.*

1.3 Guidelines for Characterizing the Product Line

This section of the CONOPS helps characterize a specific product line along a set of product line dimensions. The product line approach taken by one organization and described in its CONOPS will vary from the approach of other organizations. This significant level of variation results from the way product lines are defined and developed. These forms of variation may be placed into the following categories:

Variation	Dimensions
Product line attributes	Size, maturity, mission/market coverage
Asset procurement approach	Develop in-house, commission, acquire off shelf
Asset categories	Analysis models, architecture, components, others listed in Section 5.1.3
Asset development approach	Greenfield, legacy, evolutionary
Use of assets in application engineering	Complete/partial system, frequency of use in product development, longevity of product line
Control over assets	Used internally, internal and external use, made available for external use

Table 3. Variations to Consider in Formulating the CONOPS

This section of the CONOPS will describe the product line according to these dimensions. For example:

> *ACMY corporation has long been a leader in the pager market. However, off-shore competition has made it impossible for us to maintain our market share in the low-end pager segment. To address our possible loss of market share, we will provide a product line built on ACMYWorks that can compete in the high-level, feature-rich, two-way pager market. We will also offer ACMYWorks as a stand-alone software product for use by other pager manufactures in development of their pagers. To support external use of ACMYWorks, we will develop support tools that allow for effective black-box application of ACMYWorks in pager products.*

This example describes the product line along most of the dimensions. These product line variations will also affect the content of the *technical considerations* chapter of a CONOPS. Chapter 4 of this report will provide guidelines for how specific parameters should be accounted for in the CONOPS. The following paragraphs discuss these variations.

Some of the parameters for variation are really attributes of the product line: size of typical systems, market or mission area, level of maturity. The CONOPS should describe the product line along these dimensions. They will account for different approaches in fielding a product line that are documented in the CONOPS.

Other types of variation are derived from the product line approach: how assets will be acquired. Section 1.1 of this report described the approaches for developing, commissioning and buying a product line capability. Different assets may be acquired along different paths. There are, then, hybrid approaches that cross the boundaries according to asset type. Table 4 shows variation along two dimensions, approach, and asset type.

Approach / Assets	Develop	Commission	Acquire Off-the-Shelf
Analysis models	Organization develops its own domain model or requirements database	Organization contracts for development of models	An authoritative model or asset base exists for direct purchase
Architecture (structure of system, components, externally visible properties of components, and relationships among them [Bass 98]	In-house development based on own models	Organization provides analysis models to contractor for architecture development	Organization may acquire architecture developed externally. For example, architectures from a standards group
Components	Organization develops in-house. May use architecture developed in-house or from other source	Organization provides architecture to contractor for development of components	Organization identifies components that are suitable for use in own architecture

Table 4. Variations in Developing/Acquiring Product Line Assets

Another set of issues relates to the starting point for development of assets:

- Greenfield - the product line is a new start. The technology or product set may be so new that no legacy systems cover the desired capabilities, or the technology may drive to a new architectural approach that invalidates much of the legacy.

- Legacy - the product line may be largely derived from existing systems. Important assets such as the architecture or large-grained components may be available as assets from legacy. Alternatively, it may be necessary to provide an architecture that can easily accommodate legacy software as large-grained components.

In addition, product line development may follow alternative approaches for delivery of assets and products:

- A priori development - assets are developed for subsequent product development. Limited proof-of-concept product development may occur in parallel with asset development.

- Evolutionary - the product line will be developed incrementally through progressive refinements. Starting from a limited capability, the product line approach will generalize assets for future product line application.

Within each area of Table 4 it is possible to take one or more of these approaches. For example, some components may be developed from scratch without regards to existising legacy while other components may be mined from existing systems. Also, the analysis models may be completed in increments, starting with a core of critical domains within the product line, providing architecture and components for that core, and continuing the

evolution to encompass the entire product line. Naturally, there is overlap in these approaches and interfaces that are not strictly defined.

Variation is also dependent on the way in which assets will be used in application engineering. Assets may be used to perform the following:

- Develop complete systems.
- Use the architecture as a basis for product development with limited coverage by component assets.
- Use architecture and components for only a portion of the system.

Assets may be used in only a small number of products or in numerous systems. The longevity of the product line will also affect the way the assets may be used. The CONOPS should characterize these dimensions as well. They will affect the production plan for systems, and the extent of custom software. A generative[4] approach may be preferred over composition[5] if asset use will be frequent and can be effectively automated. If the product line is expected to live for some years, building a generative capability may also be considered.

The organization must make decisions about its development approach based on its plan for fielding the product line. For example, an organization that commissions development of product line assets may similarly propose their use in commissioning specific products. In this case, the CONOPS should describe how the organization plans to commission products using these assets. For example:

> *Proposals for new battlefield command and control systems must describe the use of Battlefield2000 assets in fielding these systems. The program office will make these assets and details of prior use in the system proposal library.*

1.4 Guidelines for Describing Readership for the CONOPS

The audience for the CONOPS document includes a diverse set of stakeholders. This section of the CONOPS should explain the message the CONOPS delivers to each stakeholder. The CONOPS is intended primarily for management, developers, and others in a management oversight or decision-making role. It contains information of interest to future reusers of product line assets who will be building product line systems and to software professionals involved with these systems and facilities where they might be installed. The intent is to introduce and discuss the concepts required to understand the product line approach to software development and acquisition.

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[4] A generative approach results in tools that automatically generate design or code for systems.

[5] A composition approach starts with components that will be integrated along with custom software to construct a system. There may be compositional tools that aid the integration process.

This section of the CONOPS should also provide an overview of the contents. The abstract of this document contains a table that may serve as an example of a contents description. The CONOPS is not intended to be an implementation or transition plan since it does not provide managers with the detailed steps involved in planning for the transition: establishing accountability, managing risk, scheduling, and budgeting. However, it does offer a clear methodology to realize the goals and objectives of the product line approach to software development. The organization may be developing documents that supplement the CONOPS, or the CONOPS may be part of a large product line adoption plan. This section also provides a description of related information being developed by the organization for the product line. For example:

- *A Battlefield2000 Business Plan will be generated for each phase and will address details of implementing the CONOPS in that phase. The Business Plan for the Development Phase covers the roles and responsibilities of organizations contributing to the Battlefield2000 development effort and outlines the process for interacting with new Battlefield2000 reusers.*

- *The Battlefield2000 Configuration Management Plan defines the processes for identifying, tracking the status of, and controlling changes to software, databases, and documentation that are critical to managing the Battlefield2000 baseline.*

- *The Battlefield2000 Developer's Guide documents the assets available to software engineers building a battlefield C2 system. The guide contains information useful in evaluating Battlefield2000 capabilities with respect to reuser program requirements and in planning how to reuse Battlefield2000 assets.*

2 Creating the CONOPS Approach Chapter

This section of the CONOPS should introduce the product line approach for developing new systems. It should also introduce an organizational structure for developing product line assets and fielding the product line. The CONOPS should explain the role that a product line architecture and components will play in developing new product line products. *A Framework for Software Product Line Practice* [Clements 99] offers general guidance in this area; the CONOPS should provide the organization's implementation of the Framework strategies. The chapter is organized into the following sections:

Developing new systems	Describes the specific approach the organization will take for fielding the product line assets and products
Organizational structure	Organization and basic tasks of product line roles

2.1 Guidelines for Describing the Product Line Approach for Developing New Systems

This section of the CONOPS provides a brief description of the approach for using product line assets to develop new systems. *A Framework for Software Product Line Practice* [Clements 99] describes both core asset and product development. It also establishes the management role in orchestrating the product line approach. This section of the CONOPS will elaborate upon the area of product development according to organizational goals and constraints. This approach may result from top-down asset development, in which assets are developed and products are subsequently deployed using those assets, or a bottom-up approach, in which legacy systems and new developments are mined for assets in future developments. In either case, this section should describe the approach for producing new systems. The next section will describe the management structure to put the approach into effect.

The Framework describes the product space, assets, and production plan as the key outputs of core asset development. These outputs are used in product development within the product line. The CONOPS may describe and illustrate the product development approach as follows:

> *A development organization works with the sponsoring organization and users to make decisions on the requirements and needs of a particular system battlefield*

*command and control system. The development organization makes these
decisions and develops requirements for the command and control system in light
of the Battlefield2000 assets. The assets and architecture-based development
offer the developers flexibility in deciding which capabilities must be mission-
unique and which they can more cost effectively achieve through reuse of
Battlefield2000 assets. The sponsor manages the development and can monitor
and validate the development of the battlefield command and control system as it
evolves from prototype to final deployment (Figure 1, Part A).*

*Rather than building from scratch, the application developer uses
Battlefield2000 assets to build a specific product in the product line. Product
development occurs through customization from base requirements and a
product line architecture. The application development organization integrates
common software components and mission-unique software using generator and
manual techniques. Figure 1, Part B illustrates this concept.*
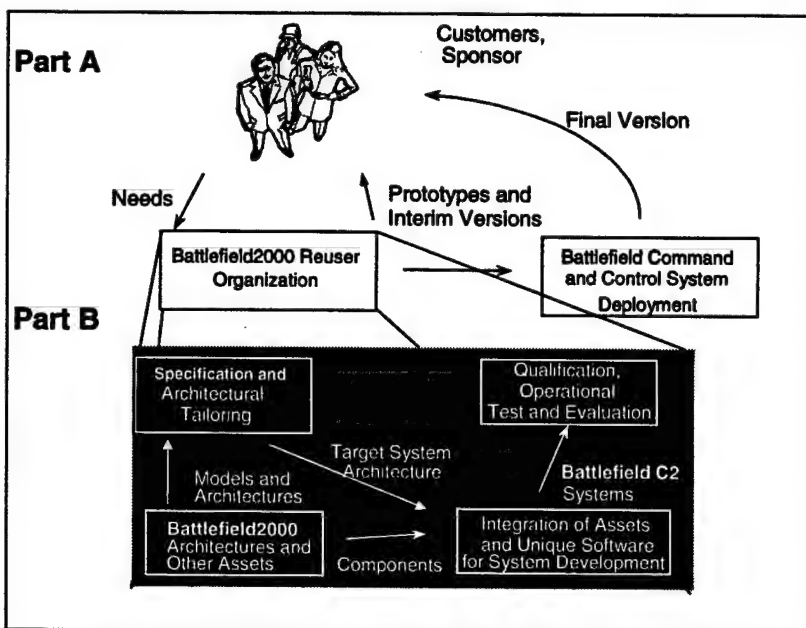
Figure 1. Product Line Approach for Product Development

Given the production plan, the CONOPS should elaborate the tasks performed by the user of
product line assets. These tasks will include the following:

- using the product line architecture for all product line products
- integrating product line component assets in accordance with the architecture
- developing and integrating product-unique component assets for that architecture
- providing products from the product line to customers
- feeding back new or modified components to the asset developers

- supporting the implementation and maintenance of the development and execution environments for product line systems

2.2 Guidelines for Describing Organizational Structure

This section of the CONOPS provides a brief description of the organizational structure for developing product line assets and using product line assets to develop new systems. The Framework identifies a number of functional activities within a product line organization including: architecture, component engineering, product line support, and product development. The CONOPS should describe and illustrate the specific groups established by management to perform these functional activities in fielding the product line. For example,

Figure 2 illustrates four functional groups within the ACMYWorks organization:

- *The ACMYWorks Architecture Group produces the product line architecture for pager products. The Architecture Group also collaborates in building specific applications by recommending use of product line assets to the Pager Product Development Groups.*

- *The ACMYWorks component engineering group develops assets within specific areas of pager product expertise for use in pagers. The asset group also defines and evolves product line architectures with the Architecture Group.*

- *The ACMYWorks Product Line Support Group defines the development and execution environments for pager products. The support group is also responsible for configuration management of ACMYWorks assets.*

- *Pager Product Development Groups develop and deliver pager products for customers. They develop a target system architecture using the product line architecture and ACMYWorks components.*
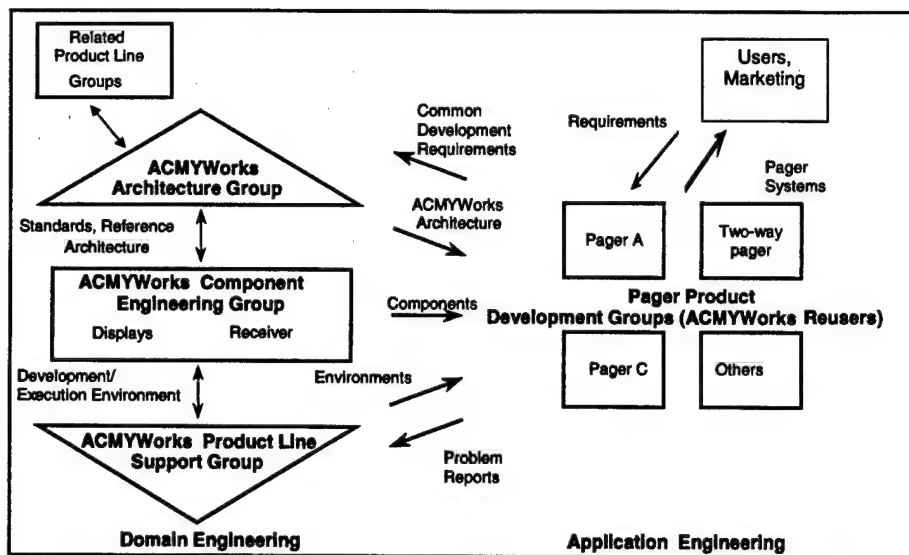
Figure 2. Product Line Organizational Structure

> *A product line approach Working Group facilitates the interactions between the Pager Product Development Groups and the other ACMYWorks groups. Working Group membership includes representatives of the ACMYWorks management team, pager marketing, and pager product developers.*

Other organizational groups are possible. For example:

- A product line organization has an architecture group but combines asset and product development groups. Under this structure, component assets are developed as a by-product of the development of individual applications in the product line.

- Another structure may share product development activities between two groups. Shared responsibility would exist when a product development is commissioned; the development activities will be performed by the commissioning organization along with the organization that was commissioned.

3 Creating the Product Line Background Chapter

This section of the CONOPS should describe the history of the product line and reasons for moving to the product line approach. This description should identify specific developers of product line products, or describe the characteristics of developers or products likely to be using product line assets. Topics to be covered may include the following:

- the need for initiating a product line effort:
  - software with reuse potential for implementing related systems
  - enterprise goals and objectives for new capabilities
  - organization targets reductions in time, risk, and cost of system development and maintenance
- an understanding of market demands and recognition that other organizations are considering product line approaches
- the inability of the organization to meet customer demand without significant change in its way of doing business

This chapter of the CONOPS will vary depending on the specific background information. It will generally contain the following sections:

Background of the product line	Activities in fielding the product line leading up to creation of the CONOPS
Rationale	Reasons for moving to the product line approach
Benefits	Benefits of adopting a product line approach
Challenges	Issues that must be addressed for successful introduction of the product line
Risks	Areas of risk that should be addressed in fielding a product line

3.1 Guidelines for Describing the Product Line Background

This section of the CONOPS should present the relevant history of the product. The organization will want to state the context in which the product line program has been developed to date. Typical product line activities include the following:

- feasibility studies

- assessments of the extent of commonality among potential product line systems

- analysis of candidate systems for the product line

- market studies to determine whether the product line can be fielded on a schedule consistent with application developer or market needs.

Results of studies and assessments can be cited to verify both high levels of requirement commonality and the ability to meet schedule constraints.

Based on the maturity of the program, the organization may want to highlight its development plans for the initial product line products. For example:

> *The Battlefield2000 Program was initiated in August 199X. Battlefield2000 development is structured as a sequence of increments, each about six months in duration. Increment #1, containing infrastructure software, was completed in January 199X. Completion of the total Battlefield2000 and initial battlefield command and control development is scheduled for December 199X.*

The organization should state its own perspective on product line assets. For example:

> *Battlefield2000 defines a reusable software architecture for battlefield command and control systems, a set of software libraries supporting the architecture, and a production plan for creating a battlefield C2 system using the software architecture and components. By providing a software baseline that supports commonly required functionality, and by maintaining that baseline across all reuser programs, Battlefield2000 offers savings in both system development and maintenance efforts.*

The CONOPS, like the architecture and other components, is a product line asset and can be used to educate new developers, provide background to potential customers, and serve as basis for long-term decisions. The brief program history should be capable of serving these as well as other needs.

3.2 Guidelines to Describe the Rationale for Moving to a Product Line Approach

The CONOPS document should help readers understand why the organization is making the transition to a new way of doing business. Issues that may be covered include the following:

- Current costs in developing new systems - These costs may be represented as time to market, level of effort, loss of market share, or inability to keep up with technology.

- Failure to leverage assets and experience across current projects - The result is relearning lessons with each new start, loss in reliability, and diverse training requirements.

- Inability to deliver increased functionality - Customers in government and industry are demanding more capabilities of their software products to keep pace with increasing user needs and processor capabilities. A major industrial corporation stopped the parallel development of four new products. It then initiated a product line that could develop those four plus future products without having to recreate functionality for each [Bass 99].

The CONOPS should clearly state the specific advantages of moving to a product line approach. The following list provides some possible rationale:

- Development time and cost are significantly reduced through reuse of technology, design, and asset qualities. Tailorable features are built into assets to meet more than one user's needs.

- Organizations build core competencies, which are concentrated areas of knowledge that allow them to make more productive use of their staff.

- Products are engineered through recognition of changes within fundamental requirements or product line architectures, rather than built from scratch.

- The organization can provide specific guidance to suppliers for vendor qualifications, development standards, and product definitions.

- Products have increased quality through the use of assets that are well understood and proven through retesting during multiuse.

- New technology may be more effectively incorporated through sharing of innovations.

- Interoperability increases through use of common architectures, interfaces, and protocols.

- Training requirements are reduced through use of common components.

Each organization will use business planning to establish its primary product line drivers. The organization should characterize its own drivers as in this example:

Major contributors to the high cost of software for our pager systems are the duplication of resources and creation of multiple systems that provide the same or similar capabilities. Redundancy in systems is evidenced by the organization developing multiple pagers performing the same or similar functions. In addition, these systems provide the same functionality as existing legacy systems without reusing an economically significant amount of existing system resources.

Most systems are built from scratch, even though they duplicate other systems in part or in their entirety.

By exploiting pager commonalities and controlling the variability across related systems, ACMYWorks will provide strategies that will enable the development of pager systems faster, cheaper, and with added capability. For the product line concept to work, a fundamental change is required in the way system requirements are defined. The product groups must be aware that they will be called upon to develop system requirements and design in light of existing ACMYWorks assets.

3.3 Guidelines for Describing Benefits of the Product Line Approach

This section will elaborate on the benefits the organization hopes to achieve in moving to a product line. As part of the decision to go to a product line approach, the organization will conduct a business analysis to establish product line goals, objectives, and strategies. For some, the motivation may be to maintain market share or technology leadership. For others, it is a matter of time to market or reduced costs. The analysis will set goals such as anticipated reductions in time to market, cost savings, and numbers of systems anticipated for the product line. The CONOPS should elaborate upon these goals and serve as an advocate of the approach. For example:

By using the product line systems approach, the Battlefield 2000 program office will deploy systems faster, at a lower cost, and with fewer resources. Our goals include delivery of two product line systems per year to battlefield command and control users. Based on results obtained during proof-of-conept system development, we anticipate a 50% cost savings in producing these systems with time to field reduced from three years to eighteen months.

System reliability will increase with the use of common components with high reliability and proven performance. Training will be improve, since common components will reduce the amount of training currently needed when transitioning staff between different systems in the product line. More commercial components will be available because industry will identify a larger market for their products when used across similar systems. Upgrades of components will also be promoted as industry recognizes a new market for their enhanced products.

These benefits and others accrue from the leverage gained through the reuse made possible by the product line approach. The CONOPS should list assets that are proposed or that exist for supporting the product line. The following assets should be considered for use across the product line:

- the product line architecture

- software components that populate the architecture of each product

- the design decisions invested in those components

- the documentation of the architecture and the components

- the performance models and performance engineering invested in the architecture for each product

- user interface design

- test plans, test cases, and test documentation for each component and each product

- processes and procedures

- personnel, who will now be able to move seamlessly from project to project because the architecture, components, and development processes will be familiar to them across projects

- project schedules, budgets, and work breakdown structures, resulting in higher-fidelity planning

The CONOPS may elaborate upon these and may be specific about their use.

3.4 Guidelines on Recognizing Challenges to Successful Implemenation

This section of the CONOPS should elaborate upon specific challenges and barriers the organization has recognized and is planning to address. The successful implementation of a product line approach presents significant challenges; but these challenges are surmountable with adequate planning. These may include the following:

- *Cultural* - Product line strategies mean organizations and managers have less direct control over their product developments and increased dependency on other organizations to understand their requirements and provide acceptable solutions. Giving up this control and the necessary dollars to support product line technology and application development may be difficult.

- *Strategic planning* - Product line planning is not only a management process that links related systems. The organization must consider the long-term needs of users and the ability to build products for those users. The organization must take an enterprise-wide look at existing and planned products and look several years into the future in planning for product lines. The future year development plans should focus attention on product lines as the means to satisfy the plan.

- *Need for tradeoffs* - The product line approach presents a tradeoff for the user between "Build me the exact system I want" and "Build me a system almost like what I want, using the product line and saving on costs and time."

- *Resource ownership* - Who will "own" the product line assets? How will they be funded? These issues require transitioning from individual product-focused organizations and budgets to a set of shared products and budgets.

- *Recognition and reward* -The current system focuses on recognition and rewards for personnel on delivered systems. Use of product line strategies also necessitates a shift to rewarding and advancing personnel for broadening the utility of products and facilitating their use within and across product lines.

- *Effects of technological change* - The transition to a product line approach will mean significant changes in our current way of doing business. We must plan for the effects this will have on the individuals who must carry out the transition and also on those who will be operating under the new approach.

- *Effectiveness of approach* - The product line approach must be measured in order to judge its effectiveness. Measurements may include typical software development metrics, but these must be adjusted to account for the development and sustainment of assets along with the use of assets in application engineering. Important measures will include: amount of change that assets must undergo for use in individual products, defects, assets that are or are not being used, and time to market.

3.5 Guidelines for Describing Product Line Risks

Introducing a product line in an organization carries with it several areas of risk. This section of the CONOPS should list and elaborate upon these. The following are examples:

- *Failure to identify a product line champion* - Success of the product line requires strong management in the form of a product line champion. For most organizations, the non-technical challenges alone will limit success unless one individual is given and assumes management responsibility. The technical activities involved in fielding a product line, from conceptualization, to asset development, to producing the first products may take several years during which no hard products are released. The champion must maintain the vision during this "black hole" period. In particular, the product line champion needs to take the early initiative and personally oversee the development of a CONOPS to solidify the conceptual approach and obtain the buy-in of key stakeholders. The champion must have authority to direct resources and establish a schedule that supports the long-term product line goals.

- *Lack of appropriate product line vision* - A CONOPS will often be written two or more years before assets are built and products start to flow from the product line. The developers of the CONOPS must focus attention on an end state—where the product line should be anywhere from three to ten years hence in order to plan for a full transition. The organization must be able to address the development of assets, their use in specific products and their refinement, and, potentially, the transition of the product line approach throughout the enterprise.

- *Failure to maintain the CONOPS* - The CONOPS is not meant to be complete and placed on a shelf. It should be constantly reviewed and revised as the product line is fielded and the product line evolves. As a document released early in the process of fielding a product line, the CONOPS can only provide a starting point for product line development. Lessons learned in asset development, initial product development using assets, and sustainment of the assets must be factored back. If the CONOPS is not maintained, at least in spirit if not as a formal document, the product line may not successfully evolve to address new customer needs.

4 Developing the Organizational Considerations Chapter

This chapter of the CONOPS should describe some of the key organizational management issues associated with fielding a product line. To complete this section, an organization must address several of the key CONOPS issues. Also, there are specific start-up activities that must be initiated. This section should also be tailored to address action planning for the organization.

The product line approach is not a case of "one size fits all." There are circumstances where the approach should not be followed because of costs, scheduling, performance, capability, or insufficient commonality. A new set of requirements may fall outside the bounds of the existing product line assets. The product line organization must then determine if these requirements should be a new area for continuing work or whether establishing a new product line is recommended. All of these factors must be considered as part of the business analysis for meeting needs of candidate users. The CONOPS should establish the process or the organizational groups that will make these decisions. This chapter is organized into the following sections:

Section Number and Topic		Description
4.1	Product line champion	Describes identification of a champion who will assume responsibility for managing and facilitating the product line effort
4.2	Architecture-based development	Establishes a development process centered on software architecture to address common and mission-unique requirements
4.3	Impact of transition	Addresses the impact of change on organization, management, and acquisition elements
4.4	Support strategy	Explains roles played in the continued maintenance and enhancement of the product line

4.1 Guidelines for Describing the Selection of a Product Line Approach Champion

This section of the CONOPS elaborates upon the importance of designating a leader for fielding the product line. The benefits of the product line approach will not be realized by just creating a set of loosely related components that attack selected specific (or overlapping) aspects of the problem. Product line systems are built from software components that are designed (or reengineered from existing systems) for systematic reuse across the product line. This systematic approach to reuse requires a systems perspective and a comprehensive plan that identifies all of the measures leading to success and the means of ensuring their accomplishment. A product line champion is the key player in achieving the success of the product line.

Understanding potential user needs, implementing solutions, and managing product evolution goes beyond creation of an architecture and components. It requires a systematic and comprehensive approach (i.e., the product line concept of operations) to marshal existing resources and identify additional methods to lower the costs of providing product capabilities through use of product line assets. Key to this is strong management support and the identification of a champion who will assume responsibility for managing and facilitating the effort. This section of the CONOPS addresses the following key question:

Issue #3: Who is/will be the product line champion?

The champion must be the owner of the CONOPS and employ available resources in concert with each other and according to the plan established in the CONOPS. For example:

For the Battlefield2000 effort, the Battlefield2000 program manager has been designated the product line champion, and is responsible for defining and articulating the integrated vision for Battlefield2000 assets and the battlefield command and control product line.

4.2 Guidelines for Describing the Importance of Architecture-Based Development

Software product line results are predicated on the use of architecture-based development approaches. Much is implied by this approach to system design. This section of the CONOPS should establish a development process centered on a software architecture to address common and mission-unique requirements and applied to the development of the system in a prescriptive manner.

The architecture-based development approach requires that a number of related elements be brought together to manage, design, implement, and test the system. The CONOPS may include or point to the following:

- a set of program plans (program management plan, systems engineering management plan, software development plan, configuration management plan, test and evaluation plan, integration plan, etc.)
- the architecture description document
- a set of architectural templates or tools that automate the representation and use of the product line architecture
- typical development tools including those for detailed design and coding, configuration management, compilers, graphical user interface builders, etc.
- documentation tools

Program plans should establish the management infrastructure and reporting elements similar to the structure of the architecture. The processes of estimation and tracking should be directly keyed to this structure. The program schedule needs to reflect a commitment of resources and time during early phases of the program for development and validation of the architecture. This usually includes sufficient prototyping to effect validation of architectural decisions and discover detail about unprecedented parts of the system.

The CONOPS may list the assets that are developed, commissioned, or purchased for supporting architecture-based development. One group may be a set of composition tools for generating system instances from components that are compliant with the architecture. The assets may include infrastructure components that provide system-wide services and structural backbone used by application components. They handle such issues as scheduling, message management, time management, security, marshaling operating platform services, synchronization, etc. Assets also include application components that provide specific functionality related to domains of the product line and system functional requirements.

The CONOPS should address the relationship of the architecture to other product line assets and to products built from those assets. This addresses another key question:

> *Issue #4: What is the relationship between the product line and product line assets, especially the architecture?*

As part of the architecture development a number of artifacts are created that are generally considered part of the architecture. These may include the following:

- architecture exploration and tradeoffs
- architecture definition
- communication of architecture in documentation
- definition of software components

- rules for architecture conformance
- technology forecasts

The CONOPS should describe the basic contents. For example:

> *Architecture is a critical asset of ACMYWorks development. The architect's responsibility includes architecture exploration and definition that will satisfy the needs of the product line in general and the individual products in particular. Equally important, the architect must communicate the architecture to those who will be building ACMYWorks components and those who will be building products. The architecture defines those software components that are candidates to become core assets. Conformance rules must be put in place for ensuring that the products in the product line conform to the architecture; that is, that no product begins to go its own way and depart from the overall architectural scheme. The architect is also responsible for ensuring that the architecture remains viable over the life of the product line; this responsibility may require technology forecasting.*

4.3 Guidelines for Describing the Impact of Transition to the CONOPS

This section of the CONOPS elaborates upon the transition to the product line approach. This transition may require significant change in existing organizations. While the CONOPS is not itself a transition plan, the CONOPS should briefly address the impact of change on organization, management, and acquisition elements. These areas will be covered in greater depth within a transition plan or other documents.

4.3.1 Impact on Organization

The product line approach requires special attention to bring together core competencies from across existing organizational structures. The CONOPS should describe an approach that will reduce or eliminate redundancy of personnel and skills within the current project-oriented organizations. This should definitely be the case if the organization develops products in house. Where an organization commissions the product line, there will likewise be a consolidation of expertise that currently supports or manages individual systems. Product line organizational restructuring will enable concentration and sharing of personnel and skills, leading to greater overall productivity. A specific action, then, is the following:

> *Action: Designate a product line champion with sufficient organizational visibility and respect, and with enough decision-making capability and authority to manage and champion the product line creation and sustainment effort.*

The *product line approach* will affect numerous stakeholders, including sponsors, contractors, and support organizations. Those actually developing product line assets will operate with a totally new set of responsibilities. Users of the product line assets, those developing products in the product line, will experience significant change in their way of doing business. The CONOPS should describe the new interactions between asset reusers and other stakeholders. For example:

> *As users of Battlefield2000 assets, battlefield command and control system developers will coordinate their development with the Battlefield2000 architecture group. These product programs will rely on both the Battlefield2000 Program and its component development group for technology expertise. The product development groups for mission-unique systems will establish the specifics for system requirements, performance, design, and implementation based on Battlefield2000 assets. As part of Battlefield2000 sustainment, the Battlefield2000 Program will review the existing product line and architecture and establish a reasonable maintenance/upgrade/enhancement plan for Battlefield2000 based on the results obtained from product programs.*

4.3.2 Management

New incentives will be needed to support the management and use of a product line approach. The CONOPS should spell out those steps that will help manage the technological changes that come with adopting a product line approach:

- addressing promotion and reward potential as it relates to product line goals and processes in the new structure

- making general cultural changes at all levels, including breaking the "not invented here syndrome"; management must drive these changes, even when they are the most affected

- integrating efforts across organizational boundaries in order to get the job done—i.e., developing a system by relying on support and assets from other parts of the organization or other organizations; not all aspects of a program will be under the control of one manager, and this will require some cultural changes

- sharing of responsibilities and resources that is impossible in a stovepiped organizational structure

- supporting certification of system conformance to the product line architecture and successful use of product line assets

- recognizing that the development of mission-unique applications requires more than just component integration

A specific action established by the CONOPS should be the following:

> *Action: Create, adopt, and communicate policies that incentivize and reward the success of the product line over the success of individual products.*

4.3.3 Development or Acquisition Policies

Under the product line approach, systems will be developed or acquired through methods that encourage the use of existing product line infrastructure. The organization must adopt policies that directly support the maintenance and upgrade of the infrastructure to support future needs. The current development or acquisition process provides resources for software-intensive efforts on a product-by-product basis, with minimal resources allocated to product line infrastructure. More investment is needed in support of a series of systems based on a common infrastructure.

The CONOPS should address many near-term changes to development/acquisition strategies. These strategies include the following:

- coordination of development activities among product line system projects and programs
- elimination of redundant development
- use of resources to further the development of the product line for the benefit of all the contributing projects and programs

The product line organization may pool funds from all the systems that fall within a product line to pursue product line development. For in-house development, a special project may be established to manage the common infrastructure. Other projects would contribute funding and software assets to evolve the product line. Existing projects may be taxed—even if they do not use the assets—as an incentive to adopt the product line approach. For acquisition via commissioning or purchase, individual projects may be taxed to cover these costs plus those of long-term sustainment. The CONOPS should establish the following:

> *Action: Create and adopt policies to decide how the generically reusable core assets will be paid for.*

Management must ensure that every new start or major upgrade is examined for potential inclusion in the product line. This examination looks for similarities with existing systems in mission and underlying functions. The goal is to focus new development on unprecedented areas and reuse product line assets as much as possible. Reuse of assets includes much more than software components. Design, architecture, requirements, and models are all assets for reuse. Policies will need to ensure that each procurement leverages past investments to the fullest and contributes to assets used in future efforts.

The CONOPS should increase the focus on assets (including non-code assets, such as architectures) and their management for use across more than one system. Use and evolution of product line assets is a key question. The organization should establish policies that assure control over the development and evolution of the product line architecture. Every system requirement that comes to a product line organization need not be accepted, however. The CONOPS should establish the following:

Action: Adopt and disseminate a policy stating the criteria to be applied in determining whether a new product should be developed using product line assets, when the assets will be extended to support a new product and when a new product is rejected as being out of scope.

4.4 Guidelines for the Product Line Sustainment Strategy

This section of the CONOPS describes the approach for the continued maintenance and enhancement of the product line and the corresponding architecture. The CONOPS should describe roles throughout the entire organization that cooperate in this effort, with the group assuming the architecture role taking the lead. Architecture maintenance and enhancement may include architecture assessments to determine the needs for enhancement or, possibly, a new architecture. Component development may include actual enhancements to product line components and ensuring that new versions of COTS products are integrated into the product lines. Product line support should include working with vendors to coordinate maintenance of their products. The CONOPS also provides for updating products for the various customers/users according to maintenance/upgrade agreements established at the initiation of a system development or acquisition. The maintenance and support of the product line architectures and components are a natural consequence of the product line development strategy.

The support strategy varies according to the approach for asset procurement, use of assets and control of assets. The following examples show differing support strategies:

- Where development and use is in house, the in-house group performing the support role assumes responsibility for sustainment.

- Commissioned assets may be maintained in house or by a contractor. The sustainment contractor may not be the original developer of the assets.

- If assets are given to another organization to be used in a commisioned product development, the product developer has little control over asset maintenance.

- Where assets are acquired off the shelf, the acquiring organization is dependent on the asset development organization to maintain the assets, and may have a limited role in determining the course of their evolution.

The organization developing a CONOPS must use these factors in establishing its sustainment strategy for assets and for asset use in products.

5 Developing the Technical Considerations Chapter

This section of the CONOPS establishes the product line approach in detail. There are specific start-up activities that must be initiated, and the CONOPS must provide a recommended set of actions. In a CONOPS document, this section presents the considerations for

- phased implementation of the product line approach
- role of architecture
- identification and maintenance of product line assets
- development and execution environments
- evaluation process for candidate users of assets

This section of the CONOPS may also include scenarios for product line asset development and product line system production. The chapter is organized into the following sections:

Section and Topic		Description
5.1	Phased implementation	Identifies phases in the process of fielding a product line
5.2	Roles and responsibilities	Describes roles and responsibilities for domain engineering and the relationship between the domain and application engineering organizations
5.3	Architecture definition	Establishes significance of architecture for product line definition, component development, and product development

5.4	Identification and maintenance of assets	Defines activities required to identify and maintain product line assets including COTS
5.5	Development and execution environments	Describes the role of the asset support group in producing environments for development of assets and for application support
5.6	Working with potential product line users	Describes process for determining when a system is appropriate for development within the product line
5.7	Development process	Describes process used to create assets and use them in developing products

5.1 Guidelines for Establishing a Phased Implementation for Fielding a Product Line

This section of the CONOPS describes a plan for fielding a product line through phases over a period of time. The titles of these phases (e.g., development) reflect the primary activity during the phase. However, the development of products and processes will not be limited to any one phase. In fact, the primary activities of the product line approach (e.g., Domain Engineering) will be a part of all phases. The phases generally described in a CONOPS and the primary activities for each include the following:

- *asset development* - creating the product line architecture and other assets; trial use

- *asset sustainment and product development* - using the architecture and assets for creating product line systems; improving the assets and refining processes for domain and application engineering

- *product line sustainment and improvement* - routine sustainment of assets and products; institutionalizing product line practices across the enterprise

The activities of these phases may be spread across several years as shown in Figure 3. Preceding development, there may be an investigative phase as well, to explore feasibility, market conditions, financial considerations, etc. The CONOPS is usually a product of that investigative phase capturing decisions made in determining a product line course of action. This section of the CONOPS will address three major issues:

Issue #5: How will the product line be introduced?

Issue #6: What is the strategy beyond product line asset development?

Issue #7: Who are the users of product line assets?
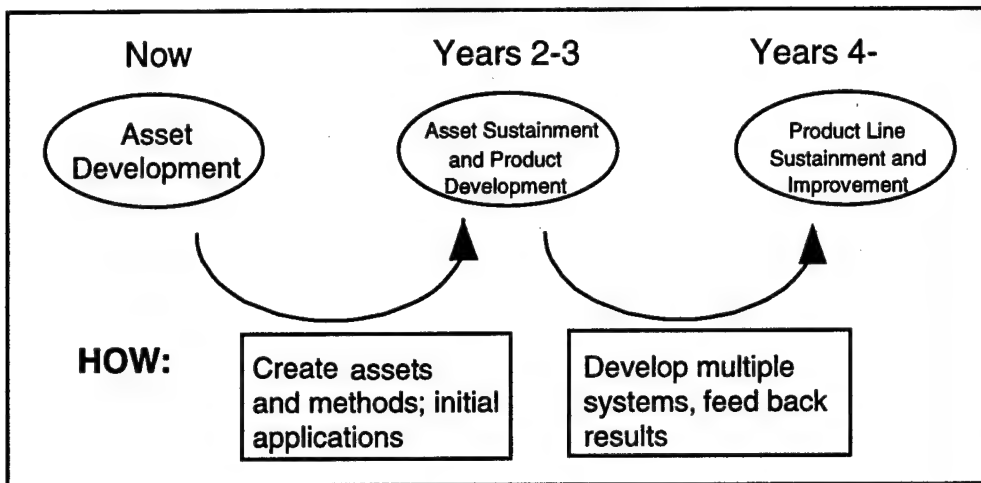
Figure 3. Product Line Approach Over Time

Table 5 shows for each phase the primary outputs, both products and processes.

Phase	Products	Processes
Asset development	• Baseline product line assets • Reuser's guide • Repository and configuration management plan and systems • Operational plan for asset sustainment and product development phase • Assessments (architecture, case study, etc.)	• Domain engineering infrastructure (tools, methods, metrics, training) • Mining assets from legacy • Partial application engineering infrastructure • Assessment methods (architecture, reuse, etc.)
Asset sustainment and process refinement	• Multiple product line systems • Improved product line assets • Application developer's guide • Operational plan for product line institutionalization • Assessments	• Application engineering infrastructure • Feeding back new assets • Reengineering of legacy systems • Maintenance of systems in the product line
Product line sustainment and improvement	• Multiple product line systems • Improved product line assets • Product line maintenance guide	• Product line production • Management

Table 5. Phased Implementation of Product Line Approach

Variation	Effect
Product line attributes	A mature product line, with significant legacy, will generally allow for a more efficient development phase.
Asset procurement approach	Asset procurement approaches (develop in house, commission or buy) will affect the activities. Table 5 assumes in-house development. These activities will largely be pursued by an organization that is commissioned to develop assets for another organization. Where a "buy" approach is used, the organization will emphasize selection criteria.
Asset categories	The asset categories will have an impact on phasing. If an architecture already exists, or can be adapted from legacy, there will be a strong emphasis on assessing that architecture and moving quickly to a sustainment phase. If not, significant effort must go into architecture exploration, development and assessment.
Asset development approach	Development approach (greenfield, legacy, evolutionary): new starts generally carry significant risk and the organization must plan for this during the development and early sustainment phases.
Use of assets in application engineering	Use of assets (complete/partial system, frequency of use in product development, longevity of product line): the types of products will vary based on these parameters.
Control over assets	Control over assets (used internally, internal and external use, made available for external use): where assets are purchased, control may be limited to participation in a user's group. Phasing may be quite different. The CONOPS may describe phases of survey (determine if assets exist in the marketplace), limited use (assurance that assets deliver on promised potential), and full production.

Table 6. Variations to Consider in Forumulating the CONOPS

The next subsections provide guidance for describing specific phases in fielding a product line. The phasing will vary among organizations, but the guidelines will apply with tailoring if another phasing is adopted.

5.1.1 Development Phase

As stated above, the CONOPS is usually a product of a product line feasibility examination. Before initiating the product line effort, the product line organization will take an enterprise-wide look at its products. An important first step is segmenting these products into product lines through an identification and scoping process. Another part of this step is mission area

analysis to define the business plan and to develop the organizational structure for product line development.

The next steps in the decision process during development include product line and architecture specification to guide the tailoring of target system architectures for individual products. These are the primary domain engineering activities. The CONOPS will provide a brief overview. This may be generic to many product lines:

- *Scoping and specification of the product line. Product line scoping defines the bounds for systems that will constitute the product line. Scoping also includes identifying those entities with which product line systems will interact (e.g., the product line context) as well as the goals to be achieved by product line development. Specification requires understanding the potential commonalities across current and future systems in the product line as well as variations that lead to different systems. This key step requires analysis of product line capabilities, those that are mandatory for each system in the product line, and those that may be optional. In addition, the definition must provide for alternative capabilities, i.e., a choice among multiple capabilities, where only a single choice is possible.*

- *Development of the product line architecture. The architecture for the product defines the components (mandatory, optional, alternative), component interrelationships, constraints, and guidelines for use and evolution in building systems in the product line. The architecture must support common capabilities identified in the specification and the potential variability within the product line. The architecture supports the development of target system architectures for specific product line systems (see Figure 4). Architecture tailoring guidelines discuss factors involved in the use and evolution of the architecture.*

- *Development of component assets. During the asset development phase, the program will rely heavily on "mining" of assets from existing programs and may purchase COTS assets. The architecture will provide constraints and guidelines for development of these assets.*

During the development phase, there will generally be one or more pilot applications built using the assets. These applications will verify the ability of the assets to meet target system requirements and will support development of the application engineering process. The CONOPS may also spell out activities specific to a particular product line:

During this phase, representatives from ACMYWorks and potential ACMYWorks reusers form a product line architecture selection team. This team collaborates in product line production with the objective of determining architecture suitability for a specific new system. The team must assess the ability of the product line architecture to meet the specific system requirements as defined by the user. This architecture assessment considers existing products in the product line, as well as architectural constraints. Existing pager products may serve as a model for the new system or the product line assets may support a prototyping capability.

The CONOPS should provide an alternative course of action if requirements for a new system cannot be met within the current product line architecture. For example:

- Can the system requirements be relaxed, so that the existing product line architecture can be used?

- Is it feasible to use parts of the product line architecture?

- Can the product line architecture be extended for new mission-unique requirements and for future systems in the product line.

- What other development or acquisition approaches are feasible if the product line cannot be used?

Figure 4 summarizes the activities during the Development Phase.
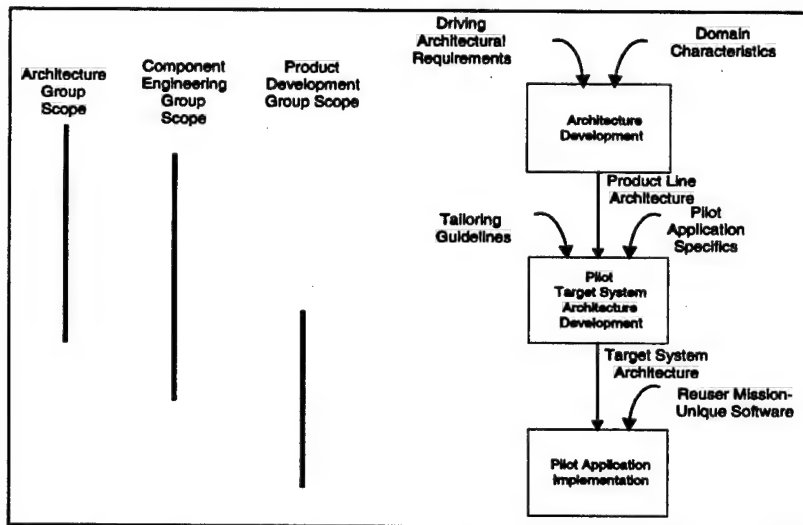
Figure 4. Development Phase Activities

Specific actions that may be recommended within this area include the following:

Action: Adopt a schedule and plan for organizational units to join the product line effort. Joining may involve active participation in the construction of core assets and derived products, or it may involve personnel training to set the stage for more active participation in the future, or it may involve participation in working groups to review the architecture and core asset design.

Action: Designate the organizational units to take part in a demonstration pilot of product line capabilities.

Action: Designate and schedule an initial (pilot) demonstration of the product line production capability.

Action: Choose the pilot products to be produced from the product line core assets.

Action: Schedule their delivery.

Action: Plan and execute a measurement program for the pilots.

Action: Build the pilot products.

Action: Assess the success or failure of the pilot effort, and plan improvements.

5.1.2 Asset Sustainment and Product Development Phase

During this phase, the organization will sustain the assets and begin to perform routine development of products within the product line. The CONOPS should describe the process for developing products as that process is refined, moving from individual pilot efforts to full-scale developments. The CONOPS should describe how the application engineering effort differs from the current historical process. For example:

- *Development from product line architectures - A group of related systems shares a common structure defined as the product line architecture. This architecture must support interoperability and component sharing with systems developed outside the product line. A new system is built by using the product line architecture to produce a target system architecture from which an implementation is constructed.*

- *Development using product line assets - New systems are composed, adapted, or generated by populating a target system. To the greatest degree possible, the target architecture uses existing product line assets. This approach to development includes formal tracking of the product line assets and identification of opportunities for reuse of the assets in other product lines. The new system architecture and any developed or modified assets become core assets for future development in the product line.*

- *Development using common environment - Products of the domain engineering phase include tools and methods for component and application development. These will become standards for both the support and execution environment during the asset sustainment and product development phase.*

The CONOPS should also define sources of variation among product line products. Table 7 lists some of the factors that contribute to potential variation. During the sustainment phase, these sources will be planned for and effectively managed.

Source of Variation	Description
System target environment	- Customer sites - Interfacing systems - Use of specific products - System workload - Operations and logistics
Target support environment	- Development facilities - Prototyping facilities - Maintenance facilities - Integration and test facilities
Customer/user	- Organizational components - Policies, guidelines, and standards - Resources - Tools and facilities - Training level and support - Technology transition support
Product line limitations	- Functional capabilities - Performance constraints - Alternative algorithms, models, or implementations - Information representation
Organizational processes	- Business/mission need analysis - System lifecycle management - Business process reengineering - Quality assurance

Table 7. Cause of Variation Among Product Line Systems

The CONOPS should define the working relationships between asset and product developers. For example:

> *Developers from the pager product group interact with the ACMYWorks architecture and component engineering groups. Together they define operational requirements and deploy systems using ACMYWorks assets, as well as their own components. Developers may also rely on the product line organization to provide domain expertise in key technology areas, such as database, communications, and network control, rather than maintaining*

organic expertise in every area. Figure 5 illustrates responsibilities of the component development group and the ACMYWorks user.
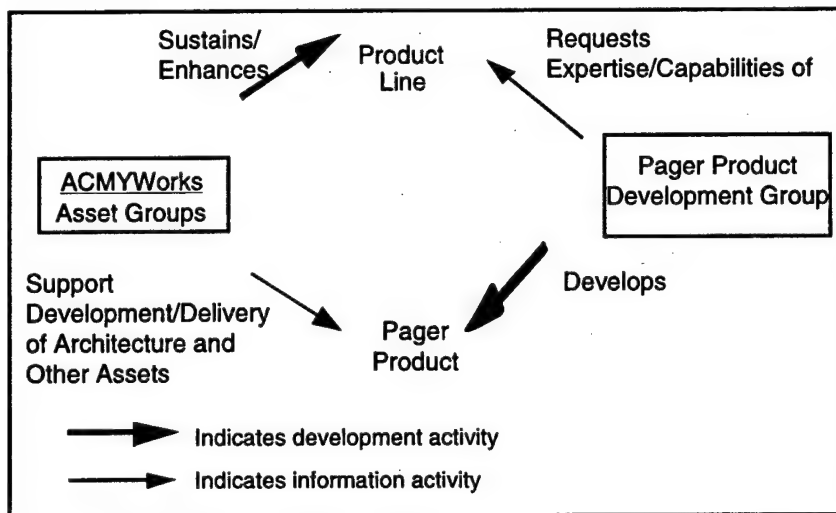
Figure 5. ACMYWorks Asset and Product Development Group Responsibilities

The product line approach may allow early demonstration of product line capabilities to a candidate user. The CONOPS should describe whether a rapid prototyping capability exists or if existing products in the product line may fulfill this role. This early demonstration informs the user of

- what other products have been built in the product line (i.e., capabilities, structure, performance characteristics, etc.)
- the bounds of tailoring
- how requirements should be analyzed and how to manage expectations
- the areas of risk—i.e., those not currently covered by the product line

Through such early demonstrations, a candidate reuser will acquire the needed information to determine whether the product line approach will be sufficient to meet all, or a useful subset, of the candidate's requirements. The CONOPS should recommend the following to support this phase:

Action: Adopt a product-line-wide configuration management and change control policy for maintaining the product line's core asset base.

Action: Adopt a product-line-wide measurement plan to assess quality and measure effectiveness of the product line effort.

Action: Adopt a product-line-wide set of coding standards.

Action: Adopt a product-line-wide testing standard.

Action: Adopt a product-line-wide performance engineering process.

Action: Adopt a product-line-wide documentation standard for system and software requirements, architecture, and reusable software components.

5.1.3 Product Line Sustainment and Improvement Phase

During the product line engineering phase, the organization will apply management controls for the continued sustainment and improvement of the product line approach. The CONOPS should provide insight into these controls and also elaborate upon the status of the product line. For example:

> *Once ACMYWorks is fully developed, application engineering from ACMYWorks will be a normal part of business, and management practices for maintaining and improving the pager product line will be in place. Product line assets will include all reusable resources that support the development of products in the pager product line.*

The CONOPS should describe which assets are being developed to support the product line. These will be far more than the software components created during earlier phases. As experience in use of product line assets grows, the assets will come to include the following:

- domain models
- domain knowledge
- product line architectures
- test plans and procedures
- communication protocol descriptions
- requirement descriptions
- user interface descriptions
- configuration management plans and tools
- code components

- performance models, metrics
- work breakdown structures
- budgets and schedules
- application generators
- prototypes
- process components (methods, tools)
- COTS product profiles
- designs, design standards, design decisions
- test scaffolding

Each development cycle of a system in the product line will offer an opportunity to refine these assets.

For the product line engineering phase, the CONOPS should describe the routine nature of maintenance of systems developed using product line assets. The CONOPS may also describe a product line asset user's group to facilitate upgrades. The user's group would include representatives from products that have used product line assets in building a system. The CONOPS should describe

- common training needs in asset development processes and product development processes that use product line assets
- how a user group recommends upgrades to the asset baseline
- sharing of experiences with other *product line* asset users

The asset support group will manage asset upgrades and changes to support the user's group requirements and ensure that changes comply with product standards and are within the defined product line scope. For this phase, the CONOPS should recommend the following:

Action: Establish an enterprise-level product line advisory group to make decisions regarding product line institutionalization.

Action: Develop a strategic business plan based on product line measurement results.

Action: Produce an enterprise-level CONOPS for product line decision process.

5.2 Guidelines for Establishing Organizational Roles and Responsibilities

This section of the CONOPS address the following key questions:

Issue #8: What are the key organizational elements for development of core assets?

Issue #9: What is the relationship of core asset development to product development?

Table 8 summarizes the technical responsibilities for four of the key roles in fielding a product line.

Element	Primary Roles and Responsibilities
Architecture role	• Establishes, monitors, and improves the processes used in the product line approach • Assesses appropriateness of product line for potential asset users • Defines, maintains, and evolves the product line architecture • With asset reusers, supports the evolution and reengineering of legacy systems for conformance to product line architecture • Defines standards and methods for validating conformance with architectural definitions; responsible for "building permits" and certifying conformance

Component engineering role	• Develops, procures, and evolves software (including COTS software) for product lines and for product line assets; responsible for configuration management
	• Supplies domain expertise in key product line technology areas
Product line support role	• Qualifies environment products against product line architectures
	• Identifies enterprise-wide development and execution assets (from COTS, government off-the-shelf (GOTS), and product development groups)
	• Provides a repository for test and training use
Product group	• Integrates and delivers systems
	• Tailors the product line architecture and components through specialization, and custom development based on system requirements
	• Performs acceptance testing of delivered systems
	• Develops plans for integration across product lines
	• Manages deployment and installation of systems

Table 8. Technical Responsibilities of the Basic Product Line Roles

Variations among product lines will affect the responsibilities. The results of specific variations are shown in Table 9.

Variation	Effect
Product line attributes	The size of typical systems or the organization may dictate that component and product development groups be merged.
Asset procurement approach	A commissioning organization will probably combine many of these responsibilities into the architecture group; the organization being commissioned will have the architecture and component groups, but possibly not the product group.
Asset categories	Decisions about which assets to develop or to emphasize first will affect the structure. There may be little component development activity if the architecture is the focus of development for the initial phase.
Asset development approach	Asset development approach - as above, the approach to development may emphasize architecture over other groups. In an evolutionary approach, there may be few, if any, component assets available during the first iteration, relying heavily on legacy.

Use of assets in application engineering	This organizational structure may be too large and its responsibilities too disbursed if the scope of applicability of the product is limited.
Control over assets	If assets are not under direct control, responsibilities are more in the nature of supplier-consumer.

Table 9. Variations to Consider in Forumulating the CONOPS

Based on this set of variants, organizations may identify other product line groups to support internal activities. For example:

Element	Primary Roles and Responsibilities
ACMYworks user representative (marketing)	• Defines and prioritizes user needs and clarifies requirements • Uses delivered systems
Senior management panel	• Establishes policy for product line systems approach; also, policy for integrating across product lines and interoperability • Ensures that all programs are identified • Approves identification of product lines • Identifies and reserves funds for product line creation and development • Approves each system to be developed under the product line approach
ACMYworks management group	• Manages system development • Serves as the primary interface to users and between other product line organizations • Supports product line identification • Uses product line definition to assist in dialog with user representative for deriving operational requirements for systems • Analyzes prototypes • Validates prototype results, where appropriate • Determines which, if any, of the original requirements can be tailored to conform to product line standards • Develops plans for integration across product lines

Table 10. Other ACMYWorks Product Line Groups

The CONOPS should recommend the following:

Action: Allocate personnel for the management and functional areas (architecture, component, support, and product development) of responsibility, as appropriate. Map the areas onto existing organizational units (not necessarily in a one-to-one fashion).

Action: Adopt (and have reviewed) a charter for each functional area, outlining the transactional interface that it has with each of the other three areas. Make sure that the charter includes a performance measurement and/or assessment criteria.

Action: Adopt a plan to ensure performance assessment for each area.

5.3 Guidelines for Describing the Role of Architecture

The CONOPS establishes architecture definition as critical to the success of the product line approach. This section of the CONOPS will address the following:

Issue #10: What is the relationship between the product line architecture and systems within the product line?

The product line architecture remains, throughout the life of the product line, an accurate conceptual model of the structure for systems in the product line. The CONOPS also describes the process by which the product line architecture is adapted as required for new systems. This adaptation is based on information discovered during design and implementation of other systems.

The CONOPS should describe the following activities. These occur within the structure provided for the product line and the constraints imposed by the architects:

- how developers of components for the architecture create system components
- how users of the architecture build systems

The architecture establishes an essential discipline, and compliance rules for designers and implementers. Key product line decisions are made during the process of developing or selecting the product line architecture. The CONOPS should address decisions based on the following questions/issues:

- What are the critical issues in product line development (e.g., product line selection and inclusion, understanding/handling commonalities and differences (i.e., domain model issues), reuse vision and strategy, security, interoperability, and reliability in product delivery)?

issues), reuse vision and strategy, security, interoperability, and reliability in product delivery)?

- What is the relationship between the domain model and the architecture?
- How will the product line support interoperability/component integration issues (e.g., the common object request broker architecture (CORBA))?
- What are the plans for compliance and levels of compliance within the product line architecture?
- How does the architecture reflect the overall reuse vision and strategy?
- Will legacy systems be supported, and how?
- How will development support requirements be handled?
- What are the plans for change/evolution management within the product line?
- What is the relationship of the product line architecture to any mandated architecture standards?
- What are the key quality factors (e.g., performance, security, and dependability) that are essential for the success of the product line?
- How will the product line take advantage of COTS or other software sharing?

The product line architecture forms the basis for producing systems in the product line. A generative approach builds the architecture into the automatic generation tool. In a composition approach, components are integrated using the product line architecture. The CONOPS should describe and illustrate this process. For example:

Component integration of ACMYWorks at the implementation stage occurs in two steps:

1. *A product line architecture is built to provide a common baseline architecture for all target systems in the product line.*

2. *An implementation architecture for a specific target system is constructed.*

This produces the following concept for building target systems (see Figure 6):

1. *The reference architecture provides the baseline for constructing a target system. For a specific pager, the components within this architecture may be tailored by modifying or adding to interfaces.*

2. *The virtual machine layer is completed for interfacing to the specific hardware configuration of the target pager system.*

Pager-unique applications are created to complete the target architecture.
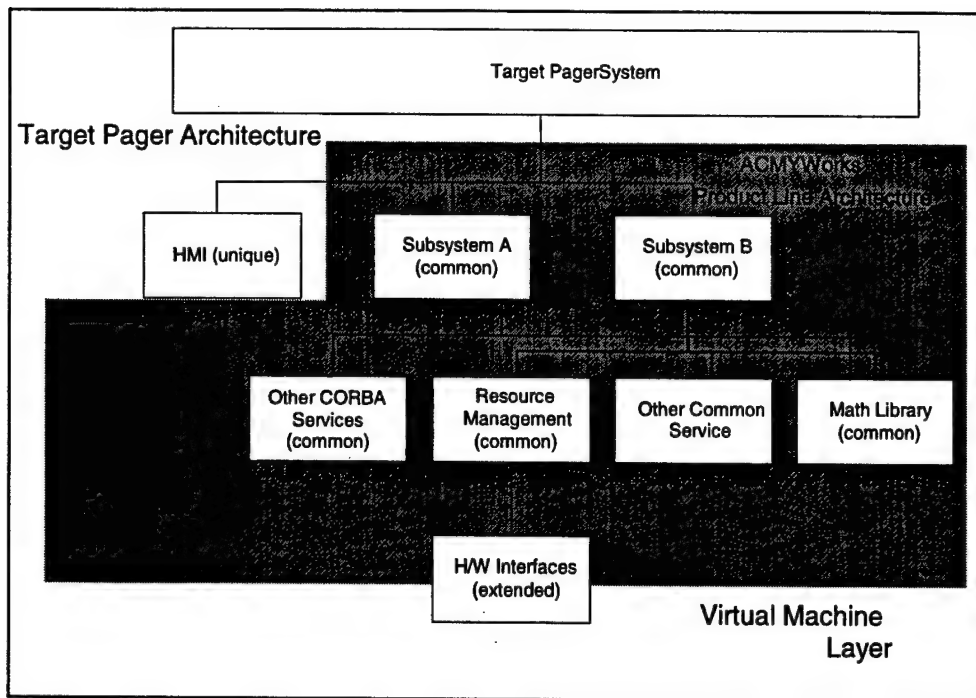
Figure 6. Architectural Layers for Product Line Assets

The CONOPS should recommend the following:

> *Action: Agree on the form and content of a specification for the product line architecture. Decide which views of the architecture (process view, module view, physical view, etc.) will be most beneficial. Decide what documentation should be available for the builder of a system in the product line that uses the product line architecture.*

> *Action: Adopt a component documentation plan that details how a component will be documented. This should include its interface specification, reuser information, documentation of algorithms, etc.*

> *Action: Specify the product line architecture. Have it evaluated.*

> *Action: Adopt a plan for updating and evolving the architecture as the product line grows from its initial pilot state through the sustainment phase.*

> *Action: Design and document a set of architectural templates or tools that automate the representation and use of architectural templates,*

> *Action: Write, review, and plan for modifying the product line developer's guide.*

5.4 Guidelines for Describing Identification and Maintenance of Product Line Assets

This section of the CONOPS describes activities required to identify and maintain product line assets. It addresses

Issue #11: What is the source of components and other assets?

These activities generally include the following:
- identifying, qualifying, and packaging reusable resources (enterprise-wide assets) for use in future development

- making them available for systems within the product line (through a repository and other communication channels)

- maintaining configuration control on versions

Furthermore, in the case where a product line has made the commitment to leverage commercial investment by focusing on the integration of COTS products as a development method, the CONOPS will set out the steps necessary to have the infrastructure in place to

- perform suitability testing of COTS products using a centrally maintained facility

Under the organizational structure of *A Framework for Software Product Line Practice*, [Clements 99] the component engineering group is primarily responsible for performing these tasks. However, the component group is supported by the other product line organizations. For example, in identifying enterprise-wide assets, the architecture group will play a major role as part of its task in developing product line architectures. For COTS products, the component group will remain the major source for identifying and determining suitability of assets.

Product line variation will affect the activities of asset identification and maintenance.

Variation	Effect
Product line attributes (size, maturity, mission/market coverage)	In a broadly scoped product line, this step may be very large. Assets may come from a variety of sources and must address a wide range of product line needs.
Asset procurement approach	The organization shifts responsibility for identification and possibly maintenance when it commissions asset development. However, the organization must exert strong oversight to assure that assets meet expectations. Buying assets requires careful assessment and specific selection criteria.
Asset categories (analysis models, architecture, components, others listed in Section 5.1.3)	The tasks for identifying and maintaining assets vary by asset category. The CONOPS may recommend individual approaches or assign these to a developer's guide or other report.

Asset development approach (greenfield, legacy, evolutionary)	Where legacy is the source for assets, mining becomes a viable approach. Greenfield asset development generally requires a more top-down approach. Evolutionary approaches may be recommended if a large number of products must be fielded in short order with assets emerging and maturing with subsequent product releases.
Use of assets in application engineering (complete/partial system, frequency of use in product development, longevity of product line)	The intended use of assets will affect the emphasis placed on packaging or need for a repository.
Control over assets (used internally, internal and external use, made available for external use)	In-house vs. external development and use play a significant role in asset identification and maintenance. An organization that expects its assets to be used by an external organization must invest heavily in packaging and infrastructure to support their use.

Table 11. Effects of Variation on Identifying and Maintaining Assets

The developers of the CONOPS should use these variants to support the decision-making process regarding their asset base. The next three subsections provide specific guidance for describing the identifications of assets in the CONOPS.

5.4.1 Enterprise-Wide Asset Identification

The CONOPS must define the product line effort to identify reusable assets for the product line and to develop a reusable asset base. Asset development may proceed as a new start, proceeding top-down from scoping and domain analysis. The CONOPS will also establish whether legacy systems must be analyzed to identify existing software for possible use as assets or other reusable information. Assets from legacy systems and new development include software, architectures, designs, criteria, and other information. This information will be maintained in a product line asset repository. Identification and packaging of these enterprise-wide assets will increase the asset base available to all product line asset reusers.

Another ongoing task to support the identification and distribution of enterprise-wide assets is cross-product line analysis. This analysis identifies opportunities for reuse of products and knowledge in other product lines. The CONOPS may establish technology transfer of this information, as well as emerging reuse techniques and methods across product lines, to maximize the benefits of the opportunities identified.

5.4.2 Repository

The product line organization often maintains a repository of assets and asset information, acquired through suitability testing and enterprise-wide asset identification activities. The CONOPS should describe the structure of the repository, the kinds of assets held, and methods of organization according to domains within the product line. The CONOPS should

also define whether sensitive information will be available through an access-controlled repository. A list of the products tested and the results of suitability testing may be made available through a separately maintained product list. Eventually, an acquisition mechanism for COTS products may be provided in addition to the product list.

The asset repository will accelerate and support availability of proven, reliable assets for incorporation into product line systems. As the repository is fully populated and the working relationships among the organizations mature, the CONOPS may be amended to define new opportunities for reuse.

5.4.3 Suitability Testing

Suitability testing is the process of determining if an off-the-shelf software product meets the architectural and functional requirements of a component area within the product line software architecture. Off the shelf products include COTS, GOTS, products of standards organizations, or freeware. The products are tested using a standard process for product line. Where suitability testing is performed, the CONOPS describes the process and suitability criteria derived from the architecture to provide an objective analysis of the functionality of the COTS/GOTS. The suitability criteria are derived from product line requirements and architecture and will be developed and maintained as a part of the assets. The results of the suitability testing of GOTS and COTS components will be used in placing these products in the approved product list for the product line.

Specific actions that may be recommended within this area include the following:

> *Action: Initiate component development activity within the appropriate development.*

> *Action: Begin a reengineering effort to modify legacy software, where appropriate, to comply with the architecture and the documentation standards. Adopt a migration plan that prioritizes this work so that the most critical components are completed first and available for reuse.*

> *Action: Identify appropriate off-the-shelf software for use as components within the product line.*

> *Action: Adopt a migration plan to add other reusable artifacts (such as budgets and schedules, test plans and test cases, etc.) to the asset base.*

5.5 Guidelines for Describing Development and Execution Environments

This section of the CONOPS addresses the following:

Issue #12: What product line support tools including generators exist or will be created?

The CONOPS will describe the environments provided for product line support. These may fall into three areas:

- *The development environment* - This includes the software development, test, integration, and maintenance environments, from development through installation. The architecture and component engineering groups use this environment to develop product line assets; the product development groups use them to produce products for users.

- *The execution environment* - This environment defines hardware/software integration on the target host for systems in the product line. It establishes actual system behavior in terms of interactions for product line products. The execution environment also supports performance analysis based on the use of specific combinations of component assets within the product line architecture.

- *The support environment* - In some product lines, individual systems are deployed through the support environment where the user provides parameters to define system operations, user characteristics, and system environments. The support environment delivers an operational system via composition, generation, or a combination of these. It may support installation. Variations among systems in the product line systems may result in differing support environments for development, prototyping, etc.

The environments may be separate products or one environment may combine capabilities.

For systems in a product line, there may be a variety of potential host configurations. The CONOPS should describe the mechanism for defining a configuration and supporting analysis. This analysis for a new system in the product line must include configurations of the various customer sites and interfacing systems. There may also be specific COTS components or proprietary systems interfacing with product line systems.

5.6 Guidelines for Describing the Evaluation Process for Candidate Asset Users

The CONOPS should describe the process for working with potential product line asset users. A candidate asset user may request information about the applicability of assets for a new system. The CONOPS will designate who will lead and coordinate an evaluation and subsequent interactions with this user. This evaluation determines if assets can accommodate the candidate user's requirements. For example:

> *The evaluation process for candidate ACMYWorks users consists of two activities: preliminary evaluation and detailed evaluation. The intent of the preliminary evaluation phase is to take a top-level look at the user's technical requirements for a new pager and determine feasibility. ACMYWorks historical data from the asset base allows accurate predictions for costs and development schedules based on pager requirements. The aim of this initial evaluation is to identify any fundamental incompatibilities that would make it impractical for use of ACMYWorks to meet the user's needs. If the results of the preliminary evaluation are favorable, the candidate user will conduct the detailed evaluation, which will establish the specific technical, cost, and schedule commitments that can be supported by ACMYWorks with regard to this user's requirements. The evaluation and analysis processes for candidate ACMYWorks users are outlined in the "ACMYWorks Business Plan: Sustainment Phase."*

5.7 Guidelines for Describing Product Line Asset Development Processes

This sections of the CONOPS addresses development processes to be used for assets and for specific products in the product line. The CONOPS establishes processes for asset development to address:

> *Issue #13: What will be the process for product line asset development or identification?*

These processes must be defined for in-house development. Where asset development is commissioned, the CONOPS should recommend steps for working with the developer. Individual products in the product line will use assets at all levels of the architecture. For example:

> *Battlefield2000 supports use of assets at all levels of the architecture for building specific products:*

- *Infrastructure assets - These are the assets that make up the reference architecture and provide services for component connection and execution.*

- *Shared component assets -Together with the infrastructure, these assets provide the common application frameworks for all applications using Battlefield2000. They will satisfy requirements for the system target architectures.*

- *System specific assets – Individual battlefield C2 systems will develop assets to support mission-unique requirements for that system. They will be built using common infrastructure, shared application assets, and system architecture components.*

The CONOPS will provide brief scenarios of the processes for creating large-grain (subsystem-level) component assets and using those assets to create product line products.

5.7.1 Developing Assets

A CONOPS will designate a specific product line organization to perform asset development. In *A Framework for Software Product Line Practice* [Clements 99], the component engineering group illustrated in Figure 2 will develop shared component assets. If the assets will be purchased or commissioned, the CONOPS describes this alternate process. Asset development will be derived from the general product line description developed by the architecture group. Assets may be developed from scratch or may be mined from legacy systems. Where assets are acquired off the shelf, the component engineering and support functions may be combined to perform asset selection. The products of this asset development will include large-grain components. The process is commonly referred to as domain engineering.

The CONOPS may elaborate the steps in this process. For example:

> *The component engineering group will follow these practices:*
>
> - *Domain scoping - From analysis of the product line description, the developers gain an understanding of the key domains for Battlefield2000 assets. These domains are actually recognized areas of expertise within the battlefield C2 community: action planning, execution, tracking, and others. The component engineering group must establish the connections and relationships between these domains and also scope their bounds of applicability. During this phase, the component engineering group will also determine which areas are appropriate for common application support and which are mission specific.*
>
> - *Domain modeling - Within each domain, the component engineering group produces a domain model to refine its understanding of the domain and then defines the domain-specific requirements. This understanding will identify areas of commonality across battlefield C2 systems and those that will differ. The domain model will be represented in the form of object, feature, and behavior models. The component group may also build and test prototypes within the domain.*
>
> - *Domain architecture - Each component asset will be integrated into the product line architecture established by the architecture group. The component engineering group uses the product line architecture as a basis for component design,*

partitioning domain requirements to subsystem and object level and defining the connections. The component design also defines details of interfaces to the component and connections to other component assets.

- *Domain implementation - Component implementation develops detailed design of the component assets. The implementation must define mechanisms for handling variation of use of the components. Variation techniques may include parameterization, inheritance, or generation. These and other implementation methods are fully explored by Jacobson [Jacobson 97].*

The CONOPS description is only a summary of a more extensive domain engineering process. The CONOPS will refer to a developer's guide or other reference for the detailed process description.

5.7.2 Developing Product Line Products

The product line architecture provides the basis for development of a specific system in the product line. The CONOPS will describe in general terms the process for creating a system. The product line organization should develop a separate guide for details. The CONOPS may provide scenarios for various steps within the overall process.

The approach to developing individual products varies widely. Table 12 summarizes the effects of some of these variations:

Variation	Effect
Product line attributes (size, maturity, mission/market coverage)	The size/complexity of the typical system may dictate the need for automated support. The type of market for the product line may affect the degree of user interaction for defining product requirements.
Asset procurement approach	The source of assets may limit their tailorability for a given product development. Product groups must be aware of the types of changes or enhancement that can be made before promising solutions using the existing asset base.
Asset categories (analysis models, architecture, components, others listed in Section 5.1.3)	Predictability will be influenced by the extent of assets available to support product development and the maturity of those assets. The CONOPS should be careful to address which areas of product development are fully covered by assets (e.g., mature, in-depth components) and those which are not (e.g., architecture has identified components, but they have not been built or are immature).
Asset development approach (greenfield, legacy, evolutionary)	Evolutionary approaches incorporate asset development into a series of product deliveries. Part of the product development activity includes asset refinement. Legacy asset development has some similarities but may, like a greenfield product line, have assets established up-front for subsequent product delivery. The CONOPS should point out the process to be established and the relationship between development of products in the product line.
Use of assets in application engineering (complete/partial system, frequency of use in product development, longevity of product line)	The CONOPS must point out the coverage of assets and where new development is expected to take place.
Control over assets (used internally, internal and external use, made available for external use)	The CONOPS should be clear about the limitations of assets purchased or available from an external source. It should also describe the interface to the controlling organization.

Table 12. Variations in Product Line Product Development

6 Developing the Recommendations Section

This section of the CONOPS recommends the order for steps to be taken in fielding the product line. This approach may be incremental and evolutionary working from the architecture and a small group of essential components. There are many advantages to the use of this approach. These include the ease of working from a small core and adding functionality progressively, early validation of system-wide design decisions, promotion of parallel development, easier integration with much greater robustness of the system concepts, and facilitation of estimating system performance, quality, and cost. Other organizations may favor a more top-down approach, where products are not produced until the asset base is fairly complete.

The CONOPS should establish the product line approach as the basis for early implementation and prototyping. This approach supports estimation of performance and quality characteristics, and the evolution of a new product line system from a small functioning core to the full system. After the initial approach is established, the CONOPS should define steps to expedite the following actions:

- Within the management organization, identify a champion and assure continuity of leadership for implementing the concept of operations. The champion provides long-term support for program management through later phases.

- Assign responsibilities for managing the overall product line approach.

- Create product line groups within the organization to perform key roles, e.g., architecture, component development and product development. Some approaches may provide for component engineering out of individual product development groups. These groups are not created for every new product line, but only when existing groups cannot or should not support a new product line.

- Analyze the current product mix to identify additional potential product lines. The analysis should review the current status of programs and the plans for future evolution. The organization must consider its current and anticipated customer base. It is possible that ongoing programs will need resources and/or relief in program milestones to assist in the development of the asset base and transition to product lines.

- Define the assets for product line development according to desired product variety and customer needs. The CONOPS should identify the processes that are part of asset creation including domain engineering, architecture description and assessment, and reengineering to deal with legacy systems. The architecture group will generally be responsible for defining and monitoring these processes. The CONOPS may designate an alternate.

- Promote the continued evolution of the product line. This includes interacting with other related systems and providing incentives for asset improvement to enhance future product releases in the areas of

  - performance improvements
  - bridges to other systems
  - auxiliary tools to facilitate the customization of components
  - documentation improvements

  - component management and change management facilities
  - platform extensions for improved portability
  - improvements of techniques for legacy system migration
  - evolutionary change to keep pace with new technologies

The CONOPS can define a transition path for promoting the use of assets in legacy systems. This should include an active search for ongoing projects that can immediately contribute to the product line approach. The CONOPS should propose methods to enhance the product line by working with these projects to make sure they are aware of product line assets, or to identify components they are producing that can become product line assets.

7 Summary

As part of the decision to go to a product line approach, the organization's business analysis will establish product line goals, objectives, and strategies. These guidelines should lead to a CONOPS that establishes an approach for achieving the goals. The guidelines also offer recommendations for developing the product line approach for a specific organization or context. They also recommend where and how to apply the product line approach.

The CONOPS describes the roles and responsibilities of groups involved in creating the product line. Where development is performed in house, the CONOPS will identify which groups have architecture or component responsibilities and whether these are separate groups or connected to specific products. For government or other commissioning organizations, the CONOPS will define acquisition/supplier interactions to develop a common architecture and other assets. While it is not necessary for the acquiring organization to own all the assets in the product line asset base, the CONOPS and the decisions it embodies must define appropriate access to them. The acquisition and ownership policy for product line architectures is currently under investigation by several groups within the DoD [Addy 98].

Product line development evolves naturally from applying fundamental engineering concepts to meeting recurring needs. Recurring requirements provide the potential for economies of scale and reuse. The CONOPS should support the goal of doing the job better, faster, and cheaper, by focusing on efforts that reduce the costs and risks associated with system development.

References

Addy 98   Addy, Edward A. "Workshop on Software Architectures in Product
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Appendix A Key CONOPS Questions

Key Question	CONOPS Guideline Examples
1. What is the product line? What mission or application area will be satisfied by systems in the product line?	ACMYworks for pager products Battlefield2000 for battlefield command and control systems
2. How will product line assets and product line products be developed or acquired? Is there an acquisition/supplier relationship?	Developed in house Commissioned Hybrid
3. Who is/will be the product line champion?	Battlefield2000 program manager
4. What is the relationship between the product line and product line assets, especially the architecture?	Architecture-based development; use of components and composition tools *Alternatively*, generator technology for producing members of the product line
5. How will the product line be introduced?	Three phases (domain engineering, application engineering, product line engineering) *Alternatively*, expand the coverage to include new domains within the product line
6. What is the strategy beyond this product line?	Identify new users, deepen coverage within the product line *Alternatively*, identify new product lines
7. Who are the users of product line assets?	Product line asset reusers, product development groups
8. What are the key organizational elements within domain engineering?	Architecture group, component engineering group, product line support group
9. What is the relationship of the domain engineering organization to application engineering?	Separate management structures *Alternatively*, domain engineering is derived from an application engineering effort
10. What is the relationship between the product line and systems within the product line?	Product line assets are used to construct a specific system *Alternatively*, one or more levels of interaction between assets and the system
11. What is the source of components and other assets?	Mining from legacy *Alternatively*, COTS

12. What product line support tools including generators exist or will be created?	Tools supporting architecture representation, asset development, composition, execution support
	Alternatively, generator tools
13. What will be the process for product line asset development or identification?	Domain engineering

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13. ABSTRACT (MAXIMUM 200 WORDS)

This report provides guidelines for an organization that is developing a Concept of Operations (CONOPS) document. A CONOPS document defines the organization's product line approach. The CONOPS document and the decisions made in its preparation will guide the organization as it plans and executes the process of fielding a product line, from product line scoping, through architecture, component development, and product development.

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